

Kennedy Space Center

Image Analysis via Soft Computing: Prototype Applications at NASA KSC and Product Commercialization.



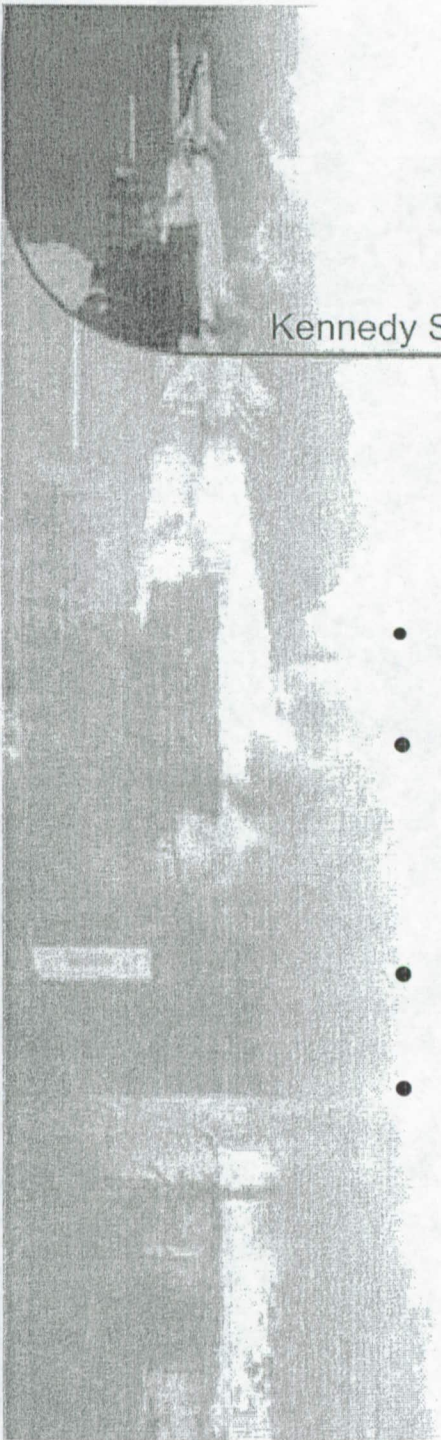
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***Jesus A. Dominguez
Steve Klinko***



ASRC Aerospace Corp.

photo: NASA/P at McCracken



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Outline



- ***System Development.***
- ***Performance results compared with existing approaches.***
- ***NASA applications.***
- ***Commercialization.***



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System Development

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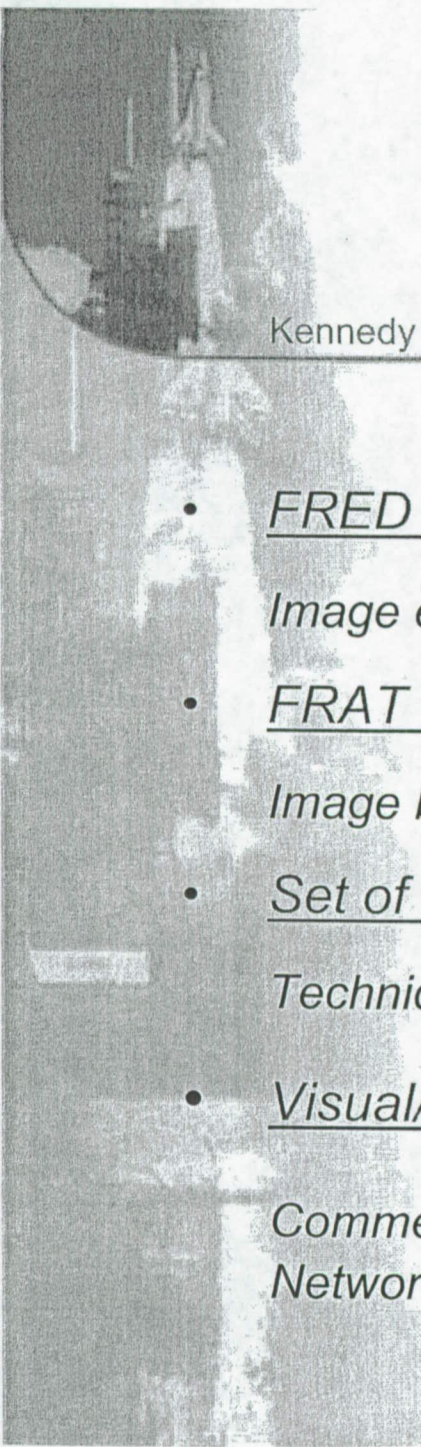
Soft Computing (SC):

differs from conventional (hard) computing in that, unlike hard computing, it is tolerant of imprecision, uncertainty, partial truth, and approximation.

provides flexible information processing to handle real life ambiguous situations and achieve tractability, robustness, low solution cost, and close resemblance of human decision making.



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System Development

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- FRED (Fuzzy Reasoning Edge Detection):

Image edge extraction technique developed at KSC (patent protected).

- FRAT (Fuzzy Reasoning Adaptive Thresholding):

Image binarization technique developed at KSC (patent protected).

- Set of Image Enhancement Techniques:

Techniques developed at KSC (one patent protected).

- Visual/Pattern Recognition:

Commercially available technique (NeuroShell) via Artificial Neural Network (ANN) and GA (Genetic Algorithm).



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Software implementation.

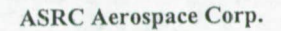
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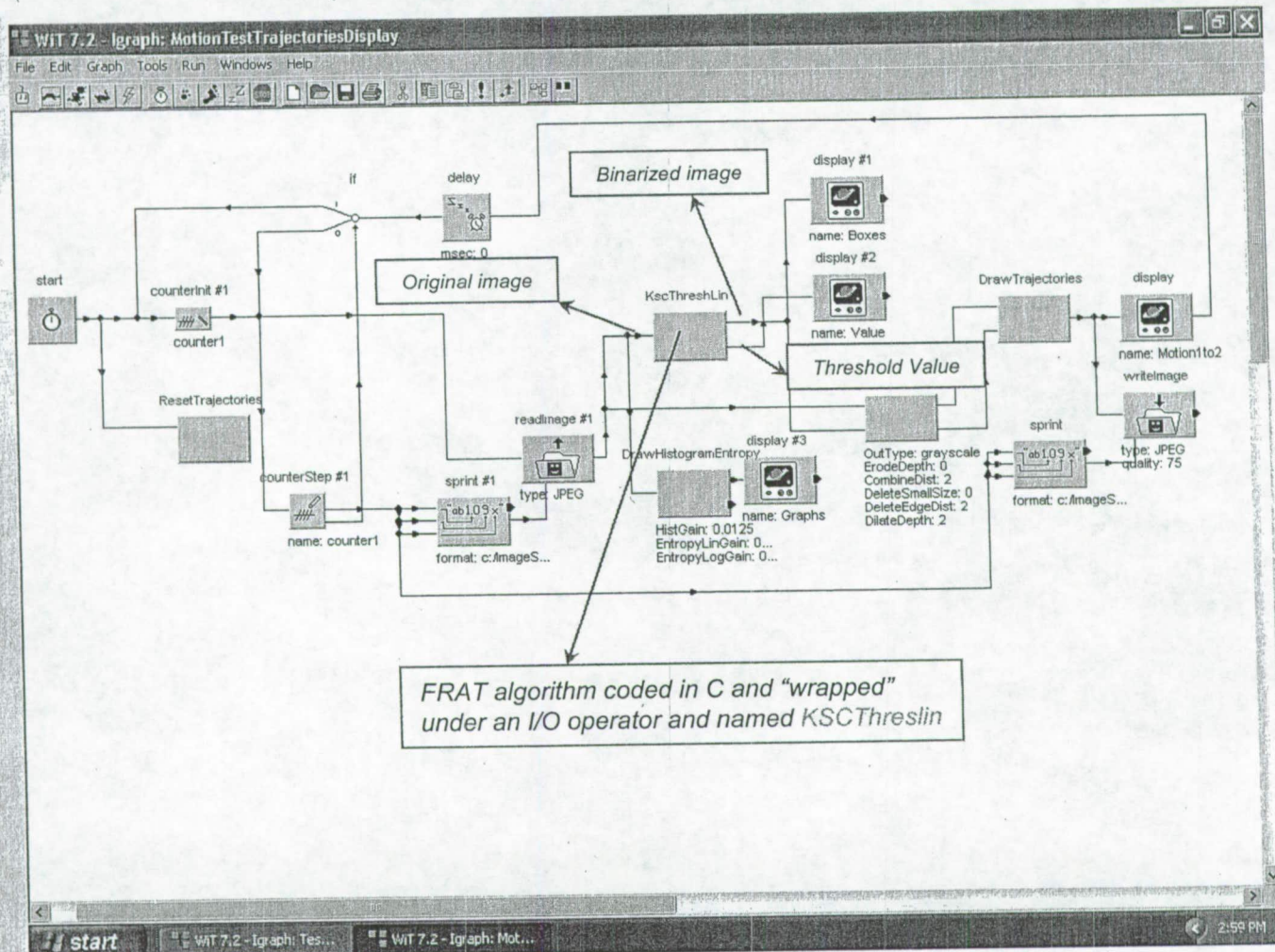
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- *ANSI C Code.*
- *C Code currently “wrapped” and embedded into a portable I/O image operator created using WIT (Logical Vision, Inc.), a commercially available image processing software.*
- *Operator has one input (original image) and two outputs, the binarized image and the optimal threshold value.*
- *User interface needed in applications created via Microsoft Foundation Class (MFC).*

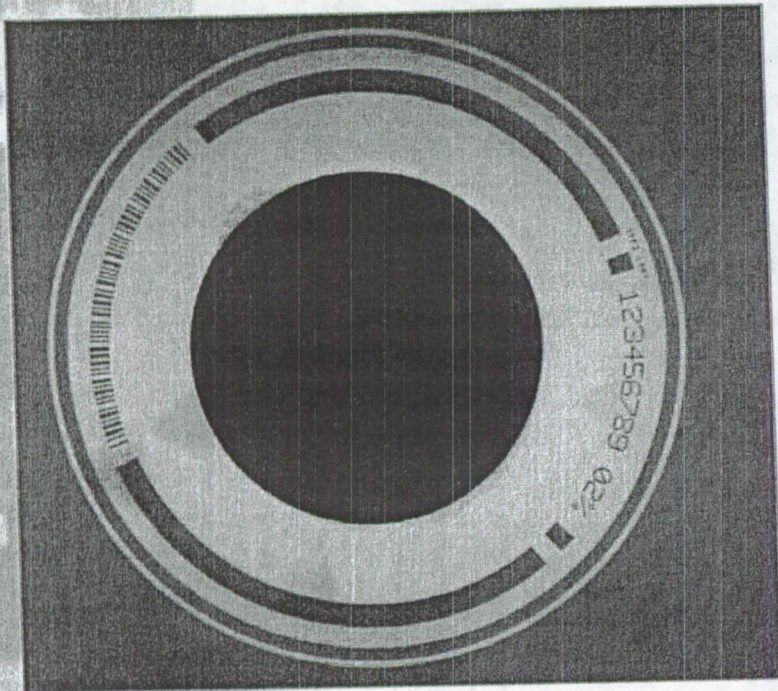


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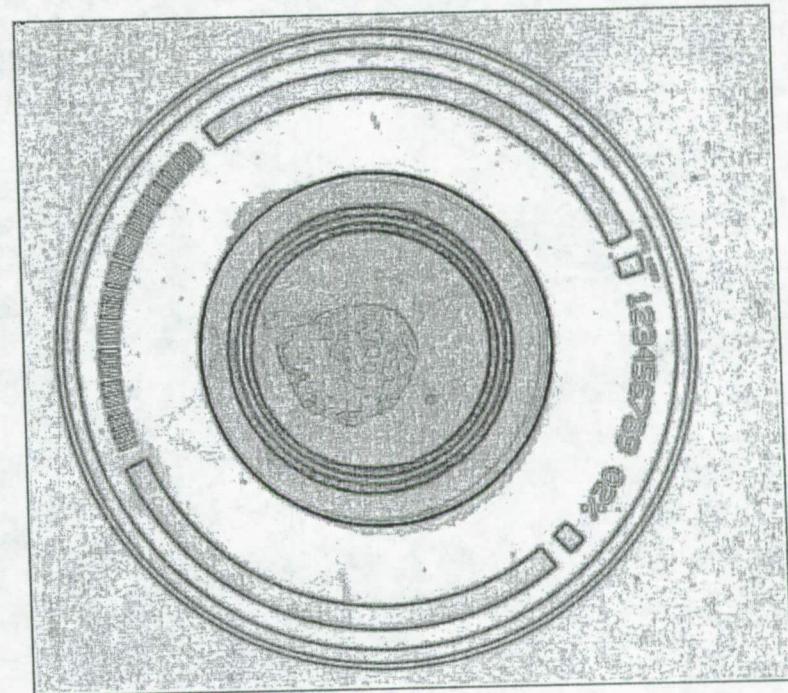


Performance results compared with existing approaches: FRED

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Original Image: CD containing a hard-to-see major scratch on the center



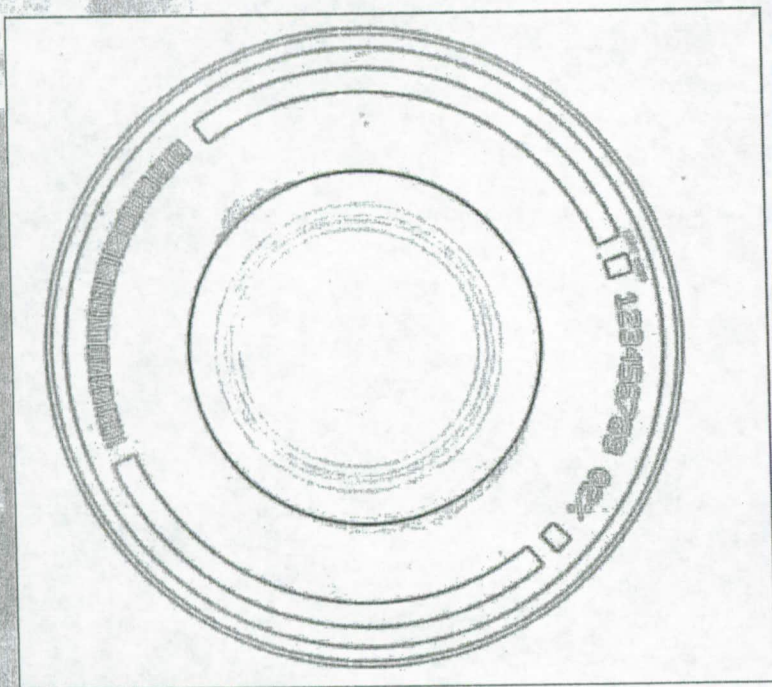
FRED: The major scratch is clearly shown as well as other minor ones



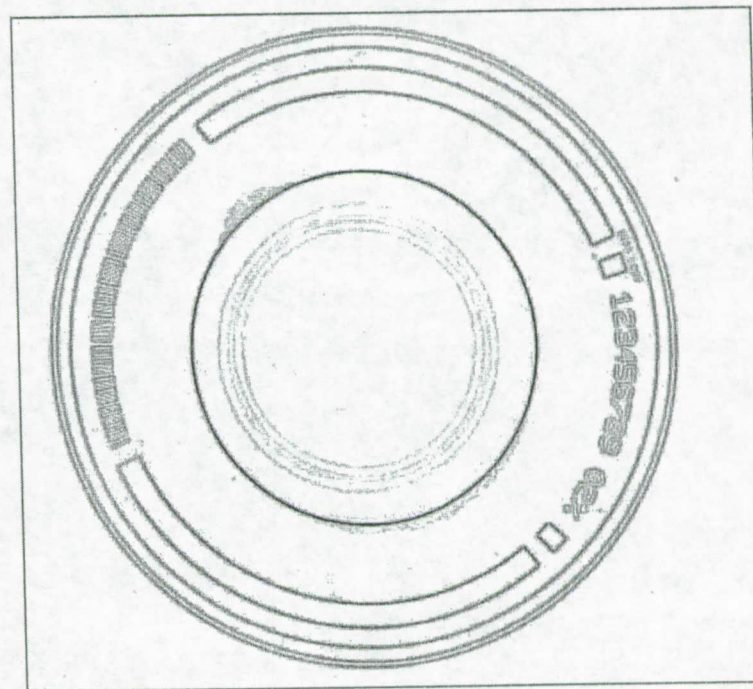
ASRC Aerospace Corp.

Performance results compared with existing approaches: FRED

Kennedy Space Center



Sobel Approach: less clear features, major scratch invisible



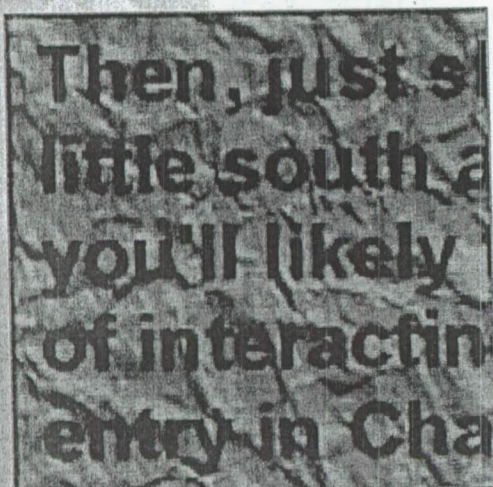
Prewit Approach: less clear feature, major scratch invisible



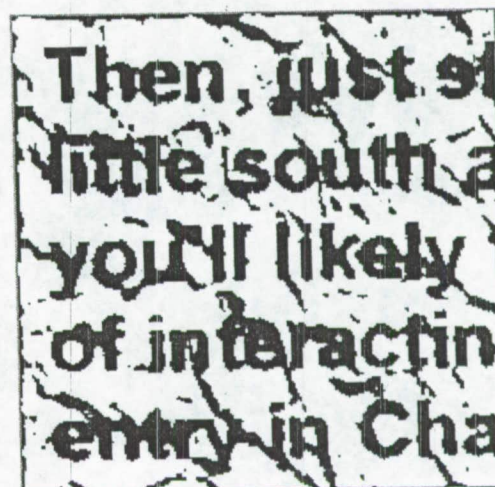
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Performance results compared with existing approaches: FRAT

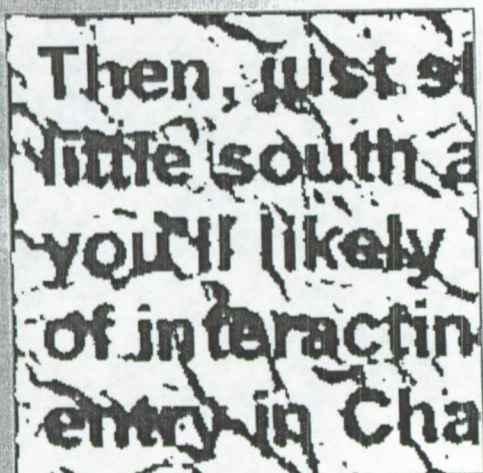
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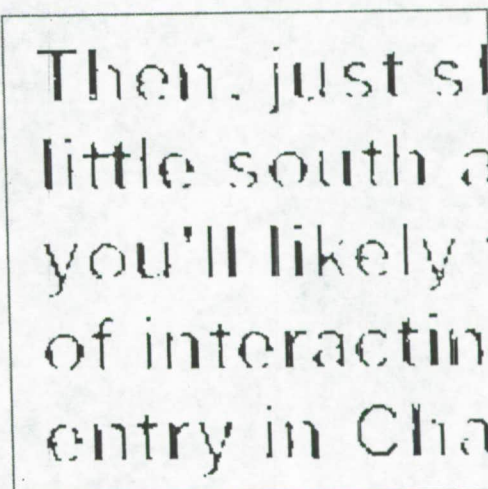
Original 8-bit Image
Size: 246×245



Otsu's Method
CPU time: 1.5 ms
Threshold: 88



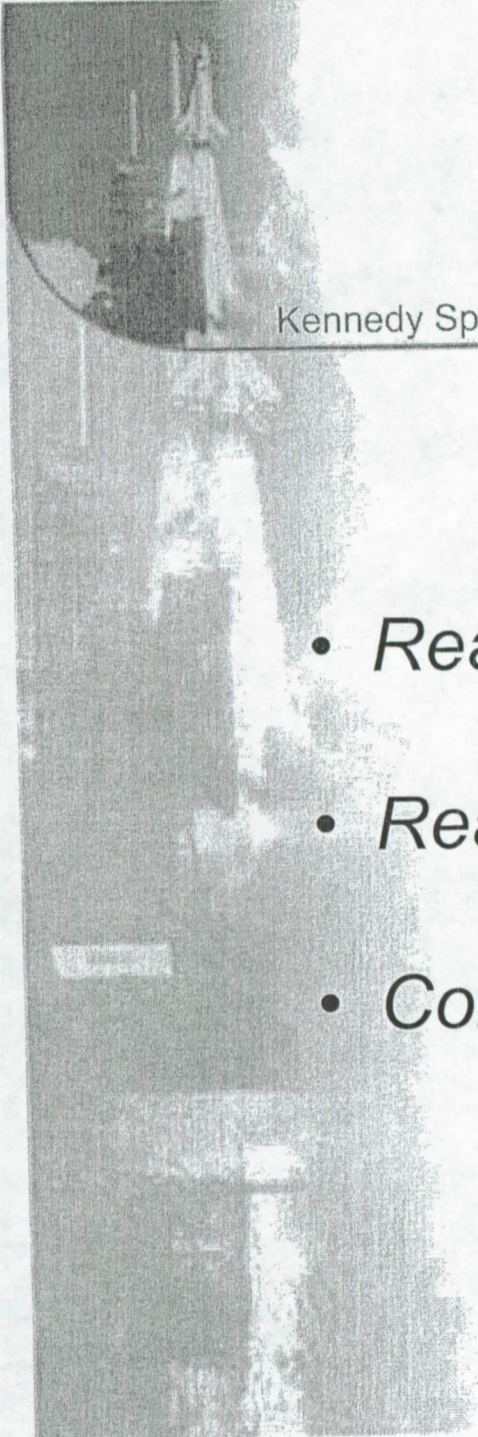
Huang-Wang Method
CPU time: 10.8 ms
Threshold: 89



New Method
CPU time: 2.0 ms
Threshold: 8



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NASA Applications

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- *Real-Time (RT) Anomaly Detection.*
- *Real-Time (RT) Moving Debris Detection.*
- *Columbia Investigation.*

RT Anomaly Detection

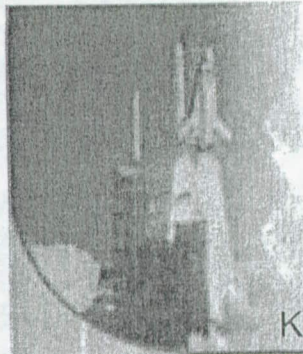


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- Image Preprocessing.
Enhancement
Segmentation (Binarization)
- Classification and Learning Processes.
Artificial Neural Network (ANN)
Genetic Algorithm (GA).

FRAT



RT Anomaly Detection

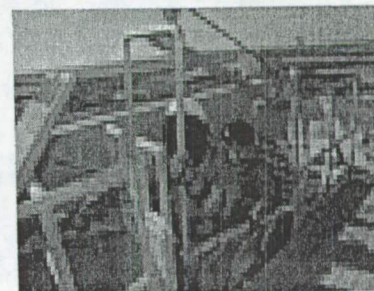


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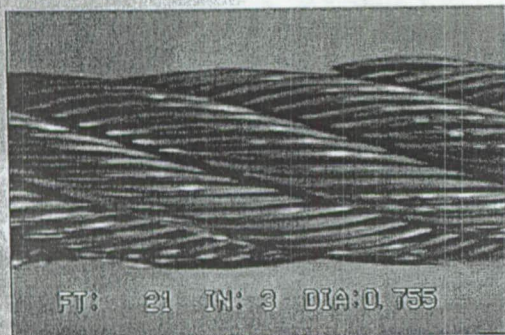
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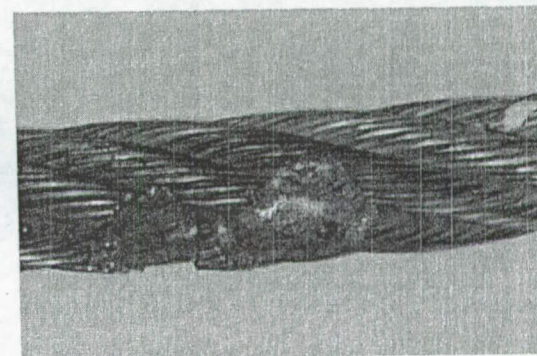
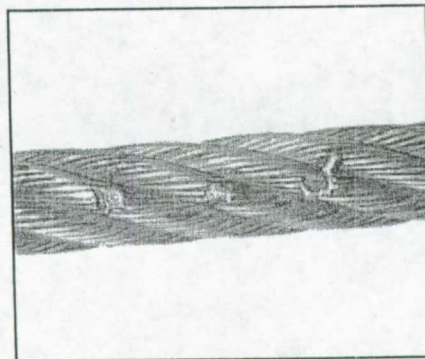
Astronauts training on the emergency egress system.



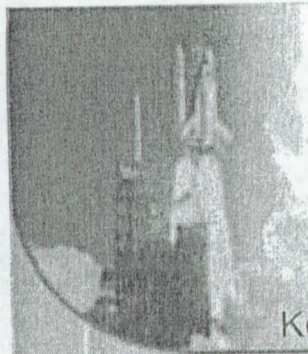
Anomalies on the basket slidewire



Broken strand.



Molten spots caused by lighting.



RT Anomaly Detection (Cont.)



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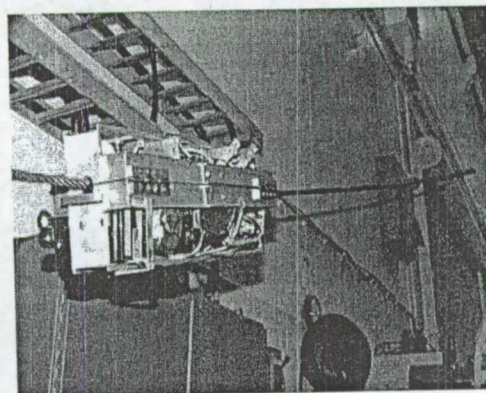
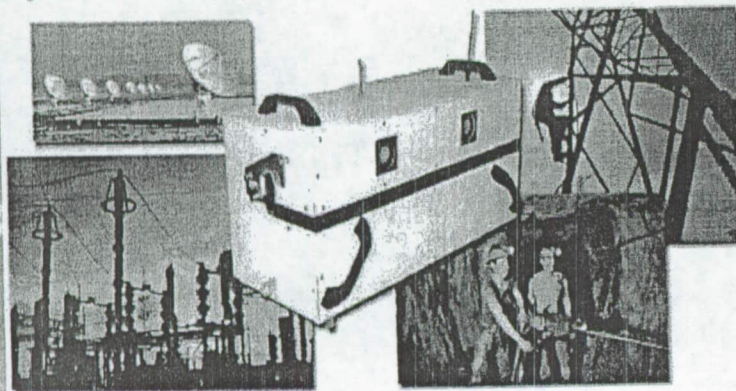
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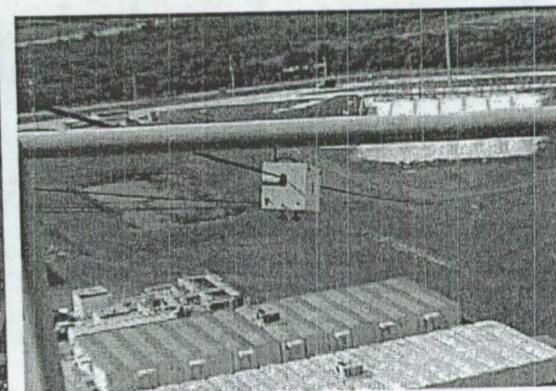
Cable and Line Inspection Mechanism (CLIM)

The National Aeronautics and Space Administration (NASA) seeks to transfer the NASA-developed Cable and Line Inspection Mechanism technology to private industry for use in commercial applications. This mechanism was developed at the John F. Kennedy Space Center (KSC) to provide a means for automated inspection of the seven slidewire cables used in the emergency egress system for the Space Shuttle. There are two sets of gantry cables plus an overhead lightning cable that require periodic inspection. These cables are nonferrous stainless steel; therefore, magnetic cable testers are not suitable for such inspections. Prior to this invention, cable inspections required 150 man-hours twice per year, with inspectors being hoisted in baskets to manually inspect the cables by

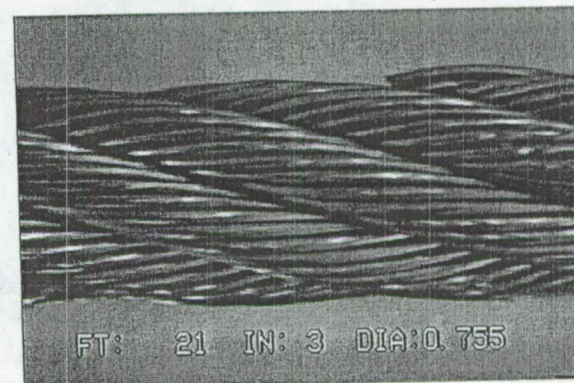
direct touch and sight. The CLIM technology eliminates the hazardous, manpower-intensive, and time-consuming methods previously required to maintain the emergency egress system at peak performance standards. In addition, CLIM is capable of inspecting the top end of ferrous wire ropes near the attachment point in the cable housing where magnetic cable testers are unable to reach. CLIM has a further application with respect to radio frequency (RF) tower guy-wire inspections. The low-carbon, low-magnetic inductance of the stainless-steel guy-wire cables, combined with added RF radiation interference from the tower, yields magnetic cable testers ineffective. Therefore, CLIM's ability to conduct a 360-degree view of the cable without incurring RF radiation interference is significant.



CLIM at the lab.



CLIM at the Shuttle Pad



Slidewire image acquired by CLIM



National Aeronautics and Space Administration
John F. Kennedy Space Center, FL

Cable & Line Inspection Mechanism (CLIM) built by NASA.

RT Anomaly Detection (Cont.)

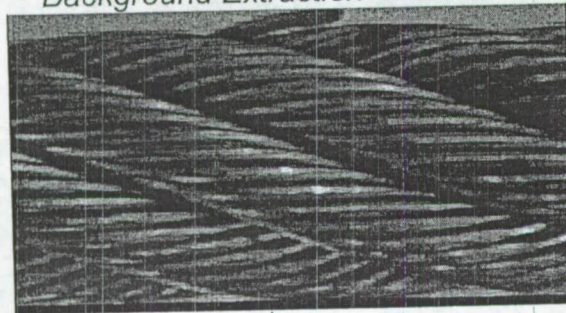


ASRC Aerospace Corp.

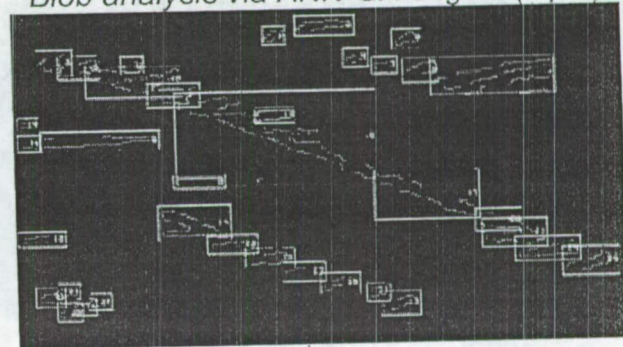
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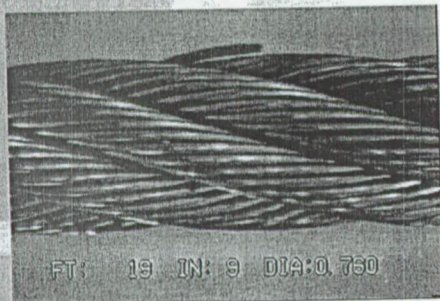
Background Extraction + FRED



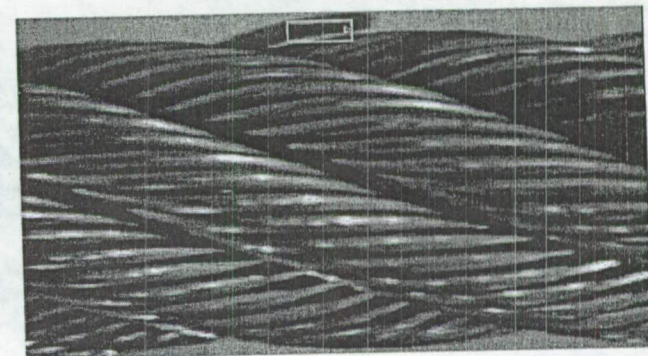
Blob analysis via ANN-GA engine (input)



Original



Binarization via FRAT

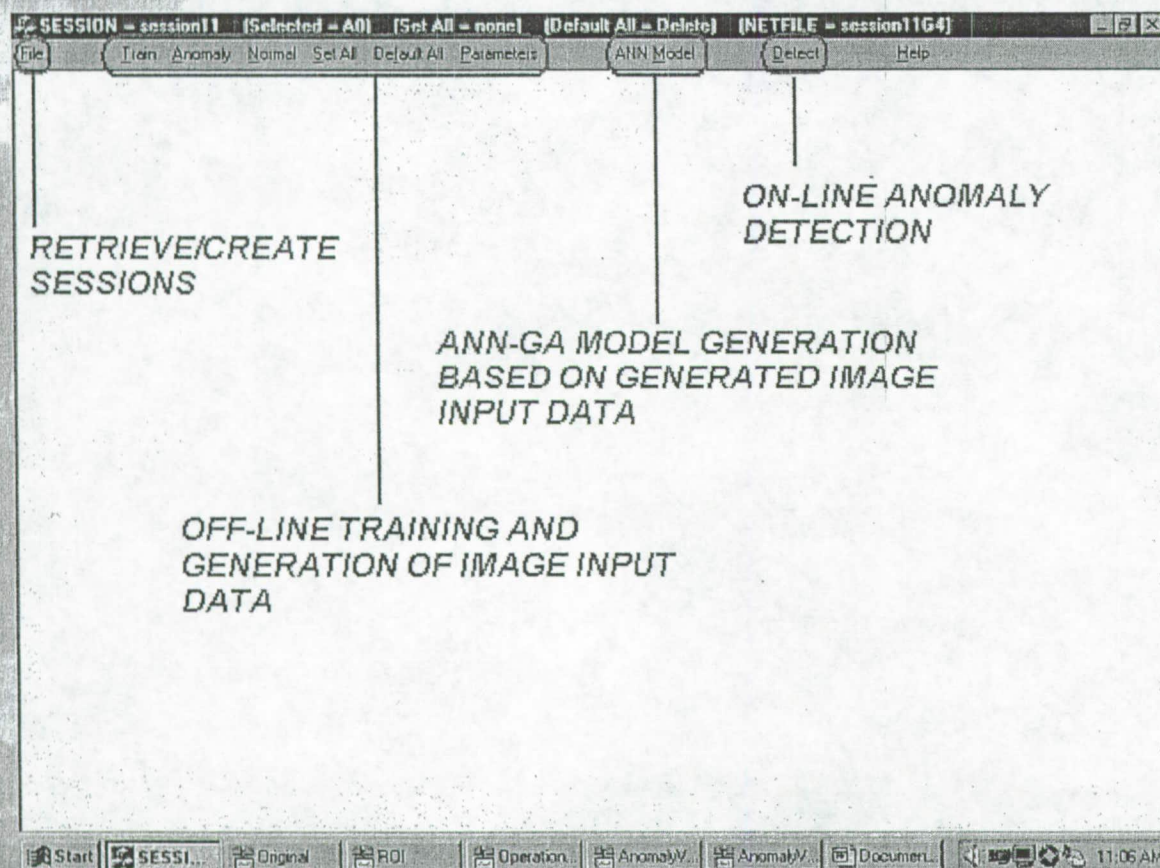


Anomaly Detection via ANN-GA engine (output)

RT Anomaly Detection (Cont.)



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*End-user front
end built via
MFC.*

Main Menu

RT Anomaly Detection (Cont.)

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*End-user front
end built via
MFC.*

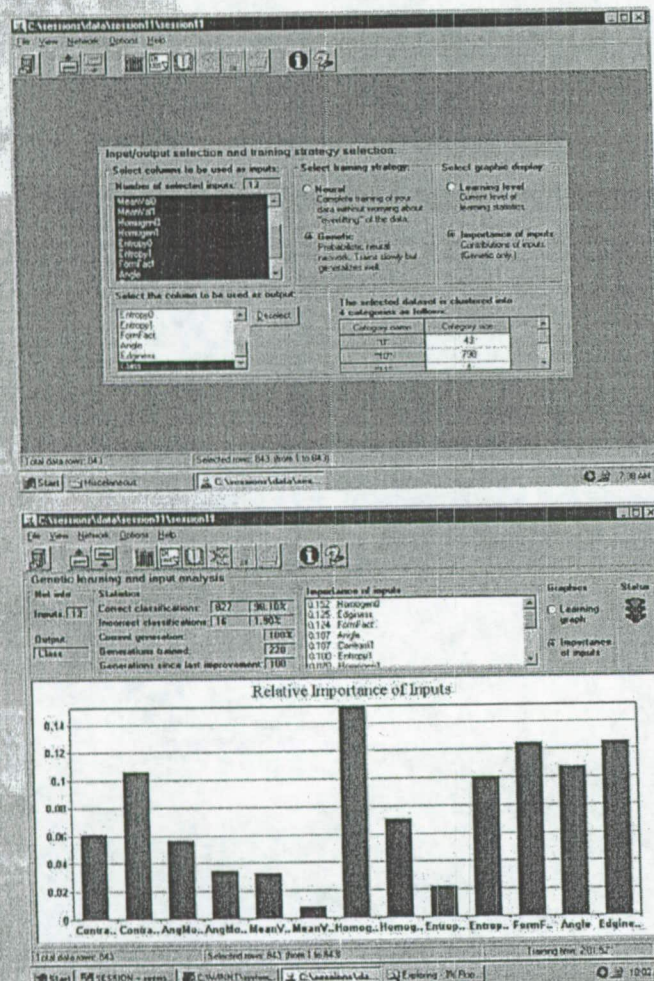
Training Stage.

RT Anomaly Detection (Cont.)

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NeuroShell Classifier - Trained Network Information

Network filename: C:\sessions\data\session11\session11G3.net

The network was trained on:

Filename: C:\sessions\data\session11\session11.dat
 Total data rows: 798
 Training rows: 798
 Start row: 1
 End row: 798

Results of training session:

Training time: 1:20:16"
 Generations trained: 178
 Correct classifications: 98.87% (789 of 798)
 Incorrect classifications: 1.13% (9 of 798)
 Performance by category:
 "0" 90.48% (38 of 42)
 "10" 99.34% (751 of 756)

Network structure:

Training strategy: Genetic
 Output name: "Class"
 Number of inputs: 13
 List of inputs and their relative importance:

Input	Relative Importance
"Contrast0"	0.006
"Contrast1"	0.163
"AngMom20"	0.074
"AngMom21"	0.018
"MeanVal0"	0.018
"MeanVal1"	0.074
"Homogen0"	0.095
"Homogen1"	0.045
"Entropy0"	0.184
"Entropy1"	0.01
"FormFact"	0.094
"Angle"	0.115
"Edginess"	0.106

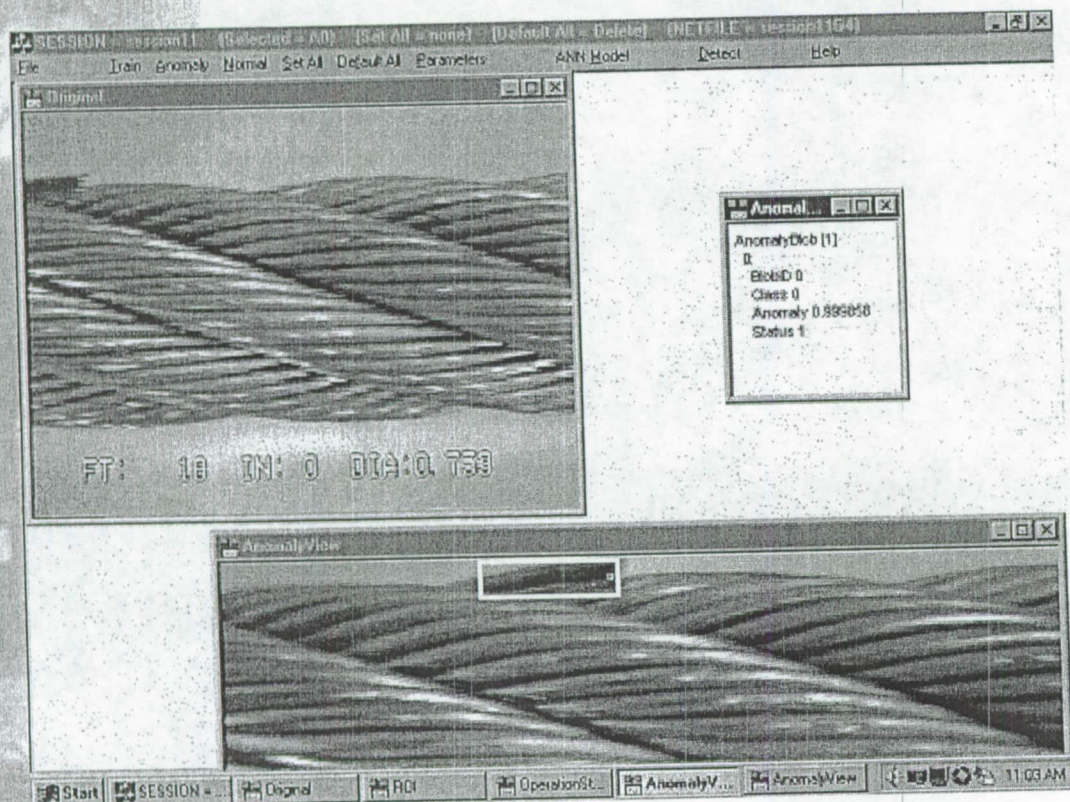
Development of
 classification
 model via ANN &
 GA (NeuroShell)

RT Anomaly Detection (Cont.)



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*Anomaly Detected
& displayed in RT.*

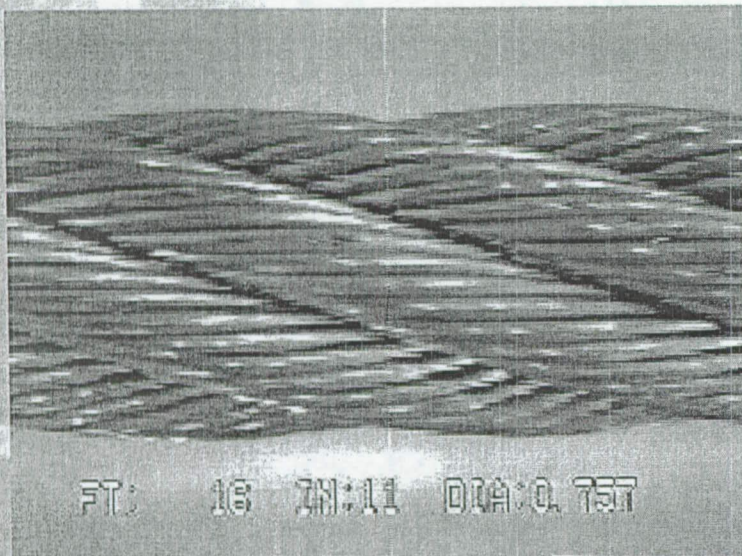
Firing stage

RT Anomaly Detection (Cont.)

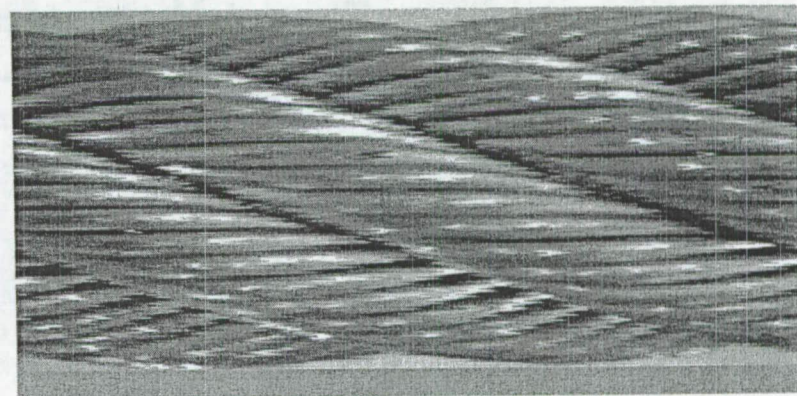
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Original image acquired by CLIM



*Automated Region of Interest (ROI)
extraction and anomaly detection.*

RT Moving FOD Detection



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- Blob Generation (single image).
Segmentation (Binarization)
- Blob/FOD Selection and Trajectory Computation
Logical path analysis (consecutive images).

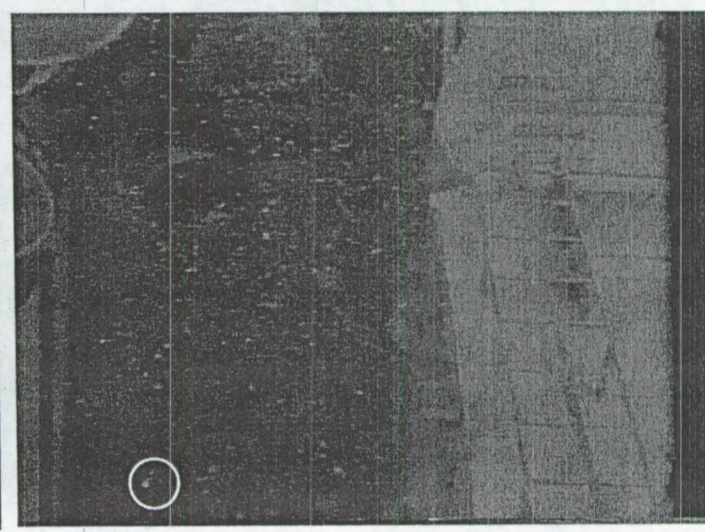
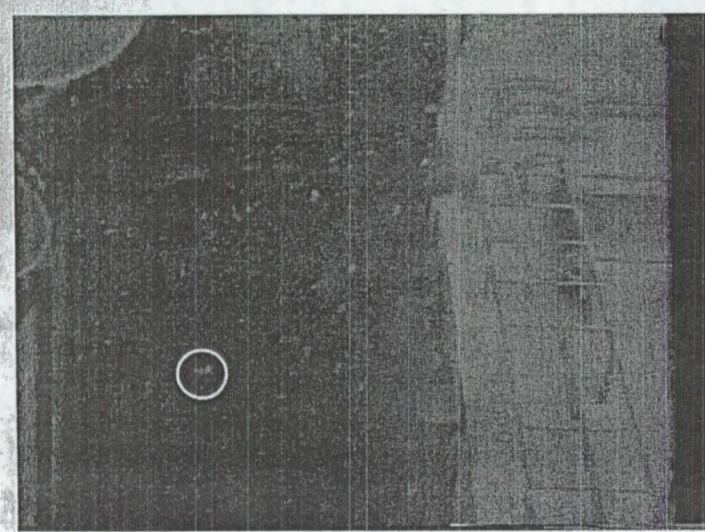
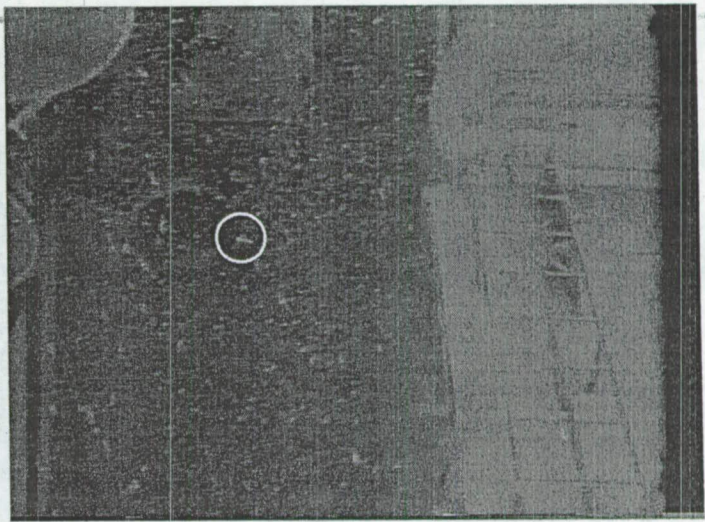
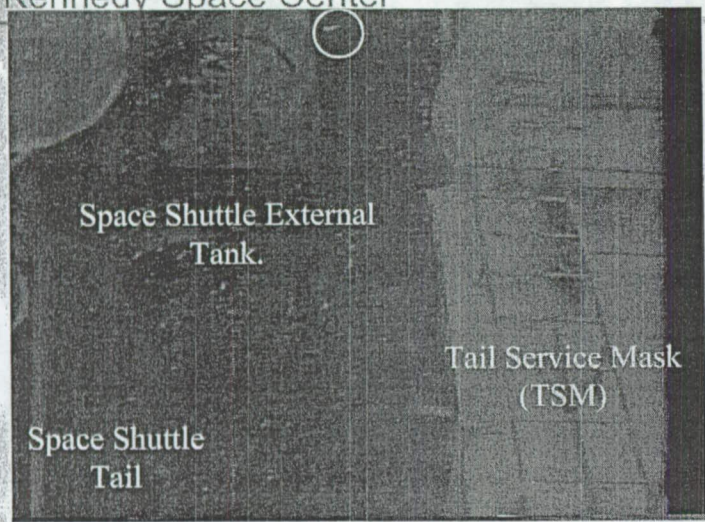
FRAT



RT Moving FOD Detection (Cont.)



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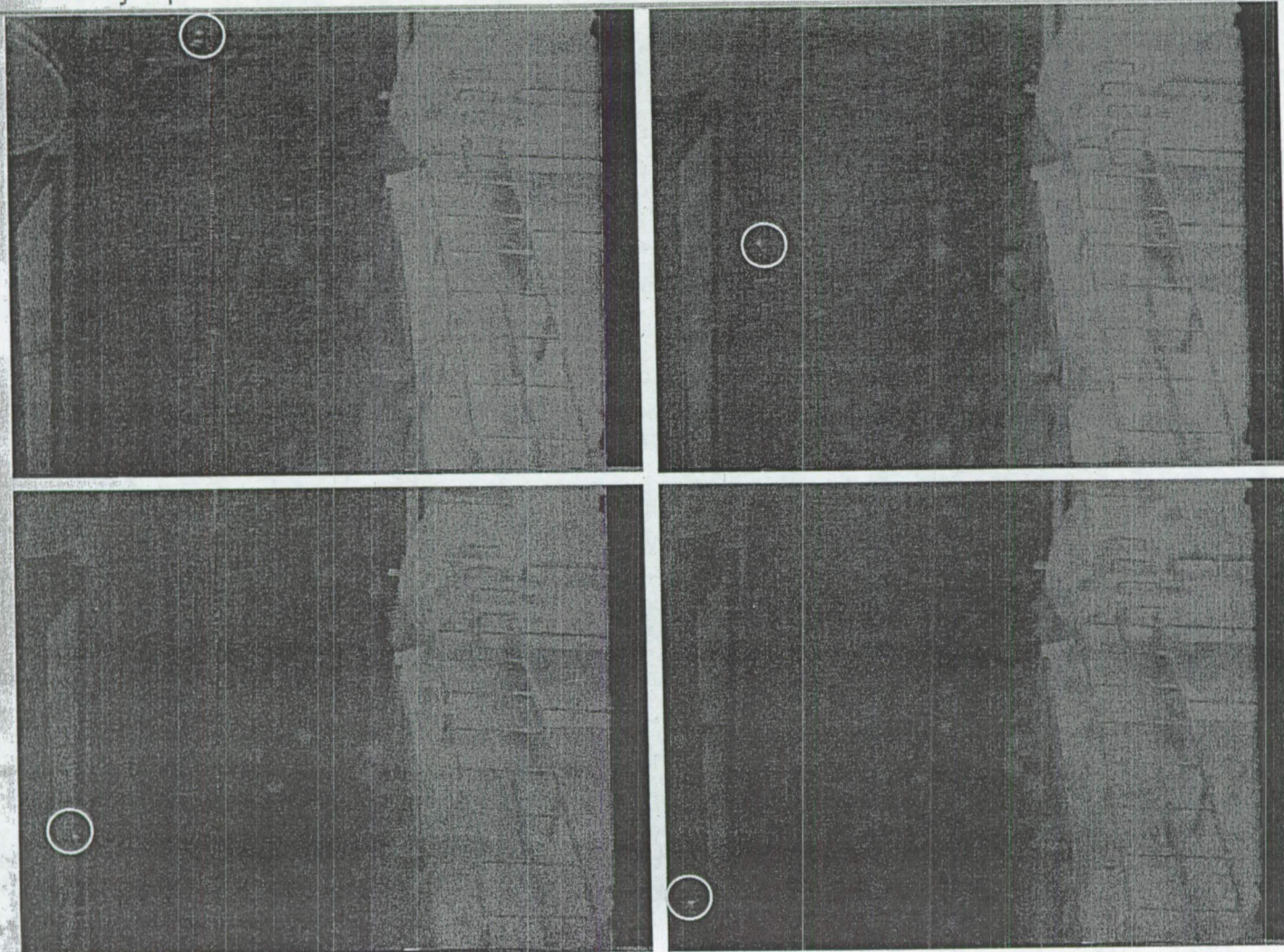


RT Moving FOD Detection (Cont.)



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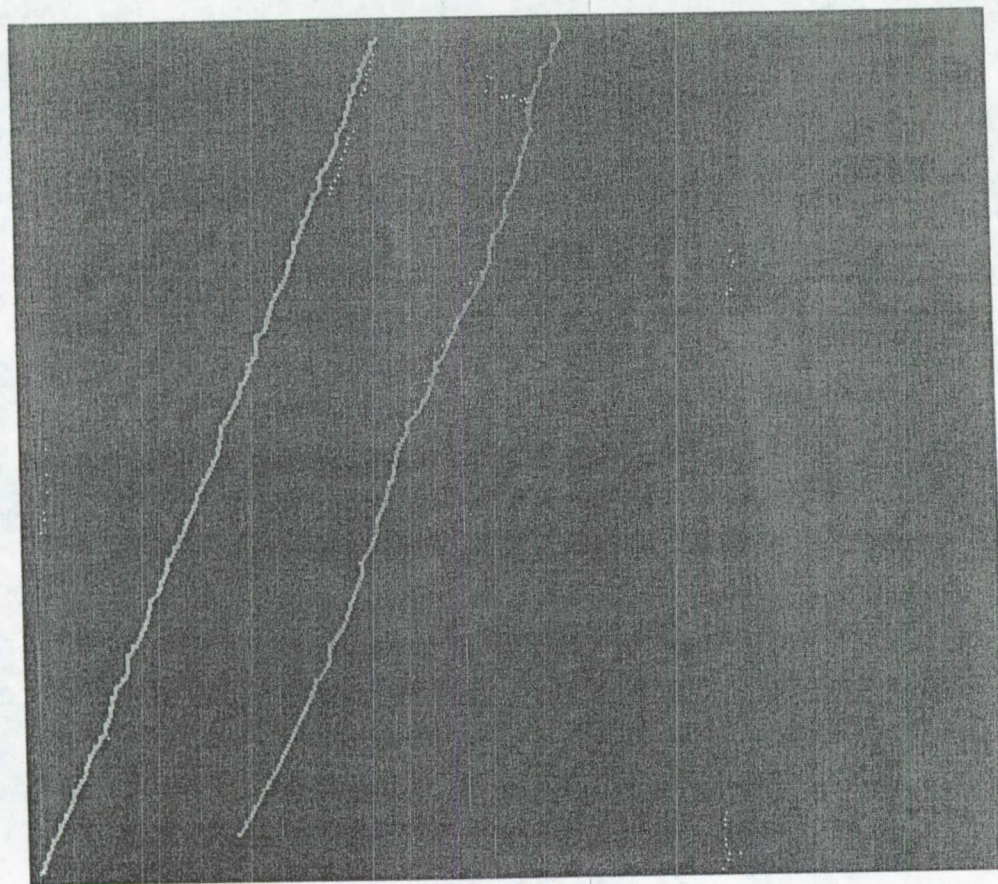


RT Moving FOD Detection (Cont.)

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Columbia Investigation



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Foam Debris

- 2D: Detection & Location.

Segmentation (Binarization)

Characterization (center of mass, borders, etc.)

FRAT

- 3D: Location & Trajectory

Optimal path at three consecutive 3D projections.

Columbia Investigation

Kennedy Space Center



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STS-107 REPORT:

***2D-Detection, 3D-Location & 3D-Velocity Estimation of
Foam Debris Based on Images acquired by E212 & E208
Video Cameras.***



ASRC Aerospace Corp.



Jesus A. Dominguez, ASRC Aerospace Corp.

NASA Kennedy Space Center, June 12, 2003

Columbia Investigation: Foam Debris Detection/Location (Cont.)

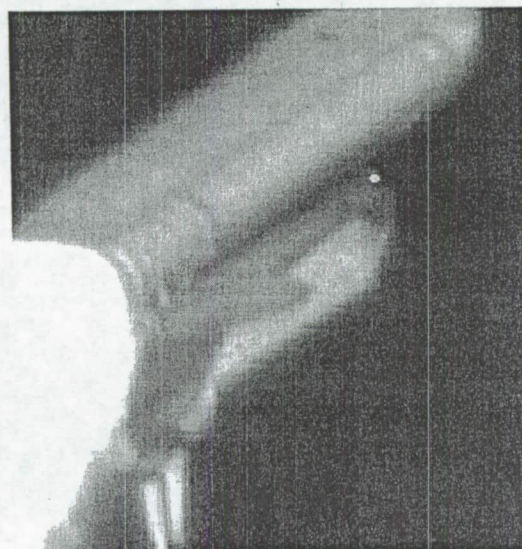
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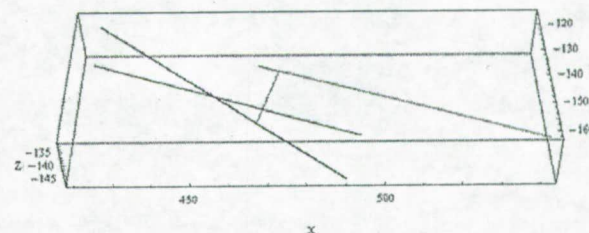
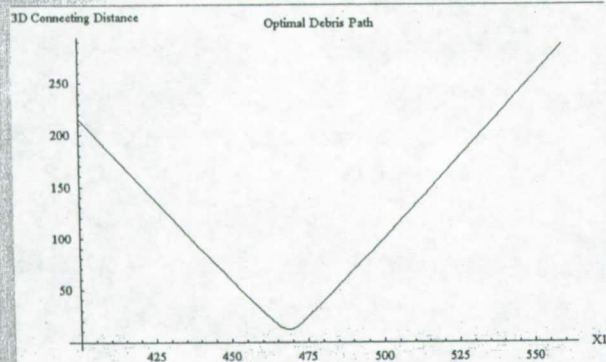
E212 at 21.753 s



ET208 at 21.757 s



E212 at 21.769 s



E212 at 21.753 s

E212 at 21.769 s

ET208 at 21.757 s

Optimized path.

Columbia Investigation: Foam Debris Detection/Location (Cont.)

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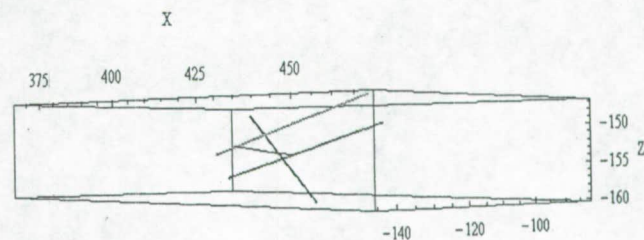
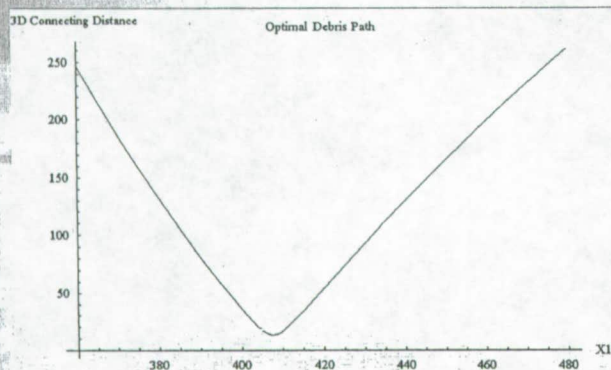
— E212 at 21.722 s



— ET208 at 21.724 s



— E212 at 21.738 s



— E212 at 21.722 s — E212 at 21.738 s
— ET208 at 21.724 s — Optimized path.

Columbia Investigation: Foam Debris Detection/Location (Cont.)

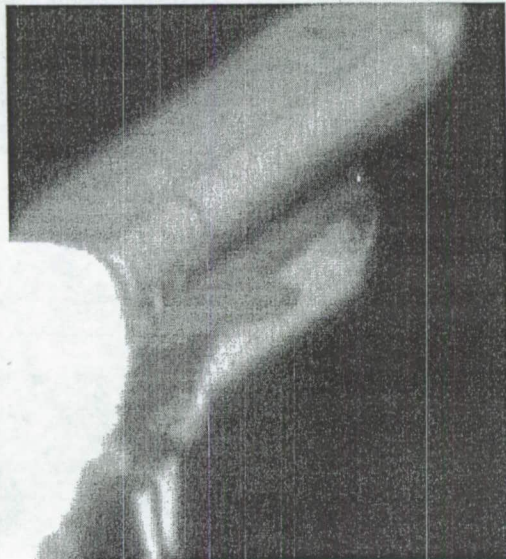
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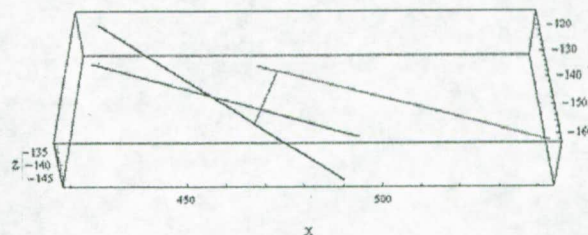
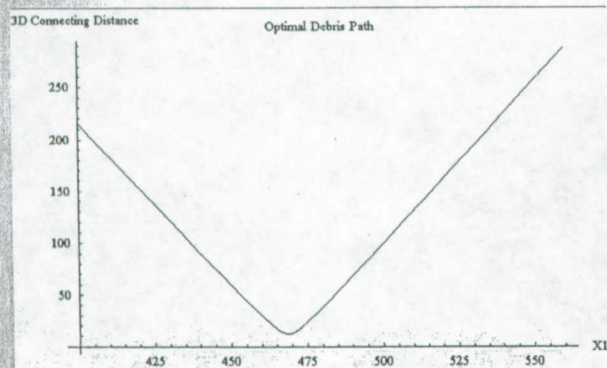
____ E212 at 21.753 s



____ ET208 at 21.757 s



____ E212 at 21.769 s



____ E212 at 21.753 s

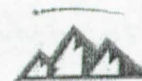
____ E212 at 21.769 s

____ ET208 at 21.757 s

____ Optimized path.

Columbia Investigation: Foam Debris Detection/Location (Cont.)

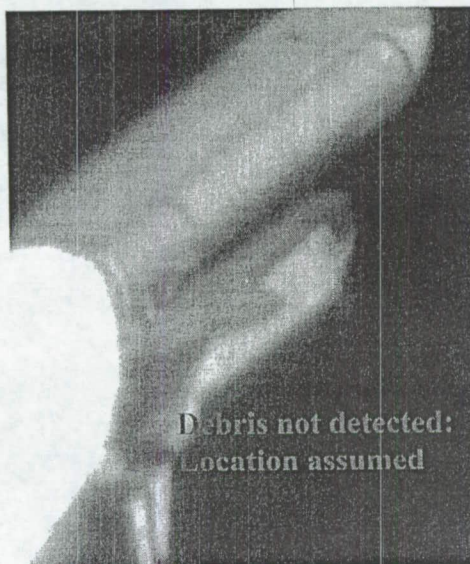
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— E212 at 21.784 s

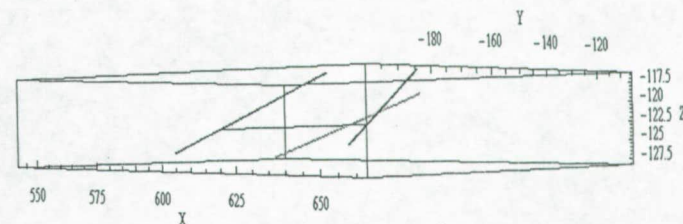
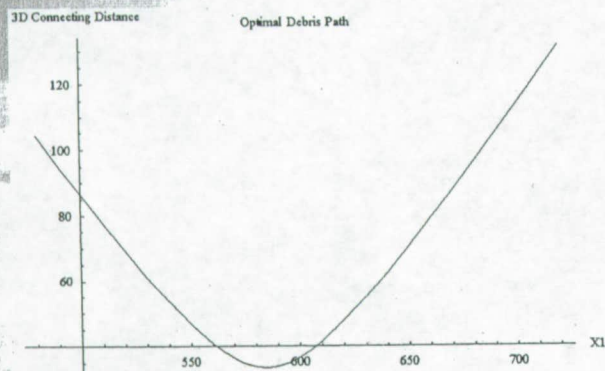


Debris not detected:
Location assumed

— ET208 at 21.791 s



— E212 at 21.800 s



— E212 at 21.784 s — E212 at 21.800 s
— ET208 at 21.791 s — Optimized path.

Columbia Investigation: Foam Debris Detection/Location (Cont.)



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E212 at 21.816 s

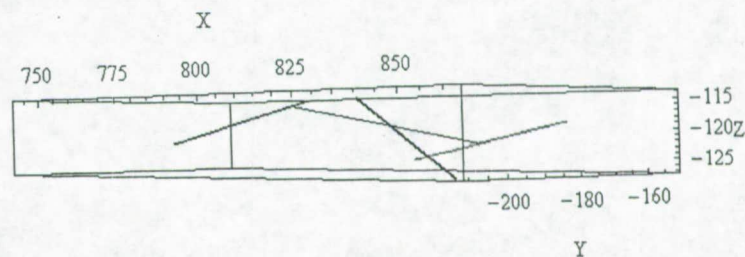
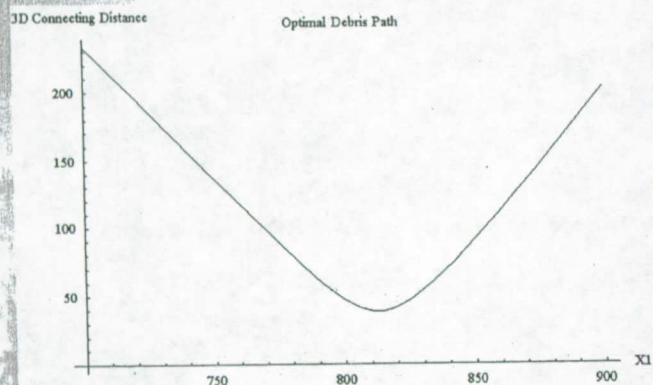


ET208 at 21.824 s



E212 at 21.831 s

Debris not detected
location assumed



E212 at 21.816 s

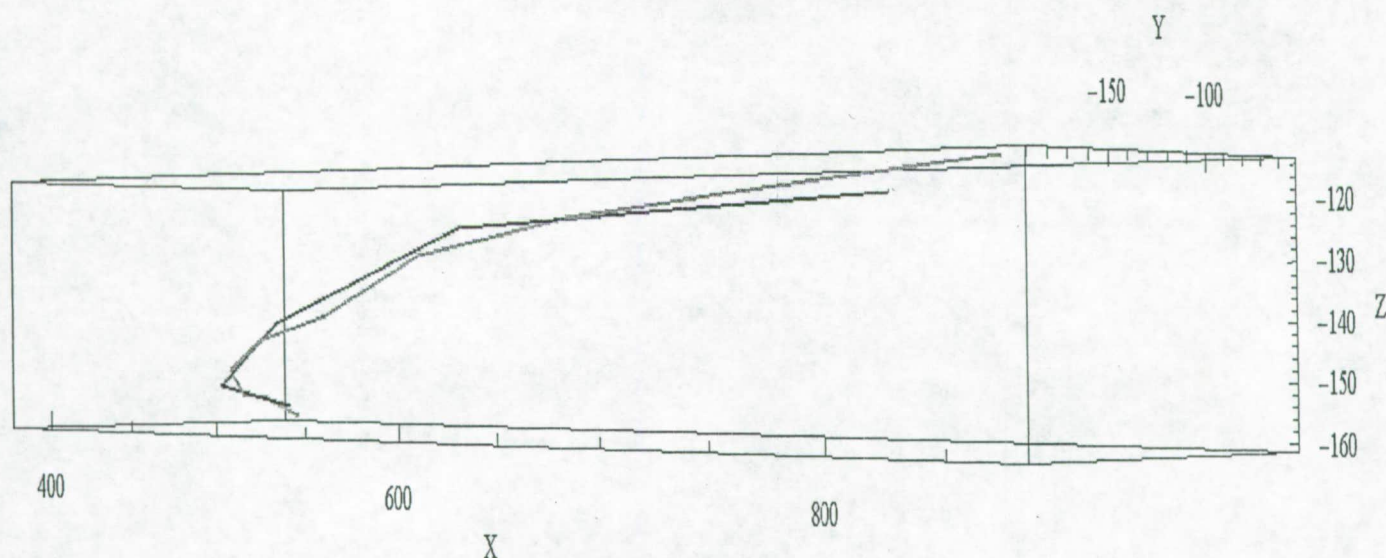
E212 at 21.831 s

ET208 at 21.824 s

Optimized path.

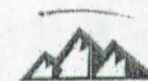
Columbia Investigation: Foam Debris Trajectory

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Current Work

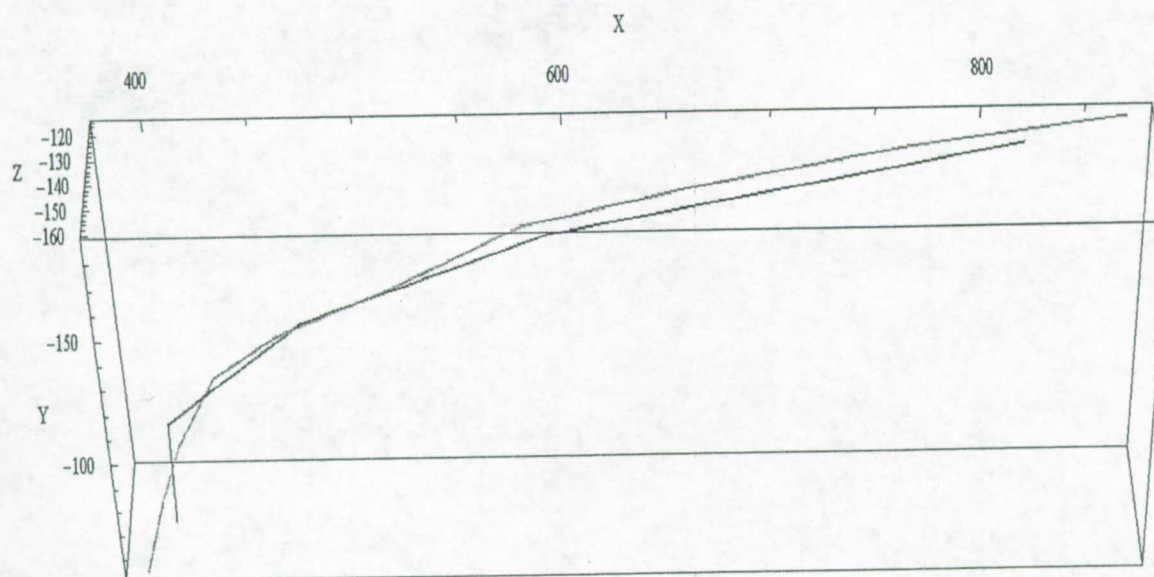
Lane-Nelson work via LighWave3D



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Columbia Investigation: Foam Debris Trajectory

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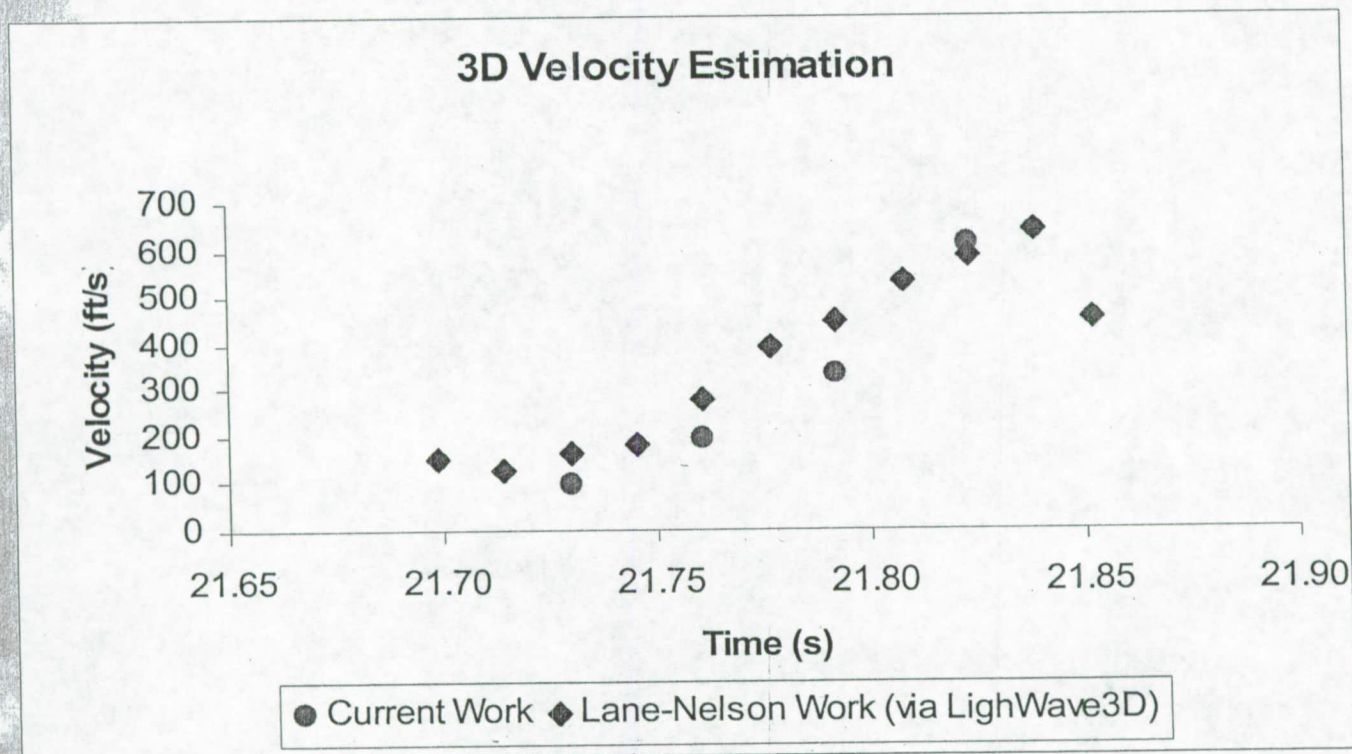
_____ **Current Work** _____ **Lane-Nelson work via LighWave3D**



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Columbia Investigation: Foam Debris Velocity

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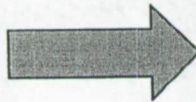
Proposed Debris Analysis Software System Development at KSC

Kennedy Space Center



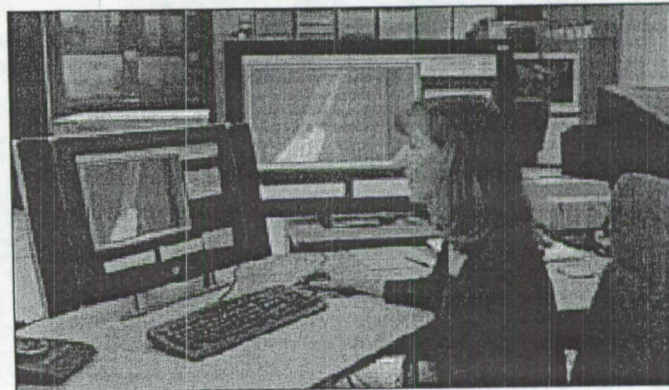
Automated Debris Detection at KSC VAB Launch Analysis Laboratory

sgi®



Microsoft
Windows

*Current OS housing FRAT,
FRED, SC-based image
pattern recognition.*



*VAB Launch Analysis Laboratory at
KSC equipped with recently acquired
SGI Reality Center facility with a 7-
foot display, and advanced SGI
TP9500 data management
subsystem.*



ASRC Aerospace Corp.

Commercialization: Licensing



ASRC Aerospace Corp.

Kennedy Space Center



Patent



NASA KSC

Technology Marketing



*Research Triangle Institute (RTI)
Center for Technology Applications
PO Box 12194, 3040 Cornwallis
Research Triangle Park, NC 27709*

NASA Technology Applications Team:

Kirsten Rieth

Phone: (919) 967-4991

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Email: krieth@rti.org

John Geikler

Phone: (919) 941-8372

Fax: (919) 941-8399

Email: johng@thesolutioncenter.com

Commercialization (Cont.)

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Technology Opportunity

First Processing Technologies

Binarization of Noisy Images A Fuzzy Reasoning Method



NASA's Kennedy Space Center (KSC) is seeking companies to license its fuzzy reasoning adaptive thresholding (FRAT) system. Used for binarization of grayscale images, this technology is faster and more reliable than current high reliability methods and is significantly effective in noisy environments.

Benefits

- Superior performance in noisy, cluttered, or textured images
- More reliable and significantly faster than current fuzzy reasoning approaches
- More efficient than ordinary binarization algorithms and comparable in speed
- Fully developed and proven effective in a critical NASA system

Commercial Applications

Currently used to analyze launch vehicle and ground data at NASA's investigation into the Space Shuttle Columbia tragedy, FRAT has numerous potential commercial applications, including:

- Medical diagnostic imaging and Computer-Aided Detection (CAD) systems
- Remote sensing, including military and earth resources
- Diagnostic applications, including seismic, GPR, SAR, and magnetic anomaly
- Biometrics, including finger, facial, and iris scans
- Optical character recognition (OCR) and other messaging applications
- Security, surveillance, and baggage inspection systems
- Industrial machine vision and inspection systems

NASA
National Aeronautics and Space Administration

Technology

NASA's fuzzy reasoning adaptive thresholding (FRAT) system is used to binarize noisy, cluttered, or textured grayscale images. Using a fuzzy reasoning technique that implements on previous fuzzy logic functions, FRAT is faster and more reliable than other current high reliability methods.

FRAT defines an image as an array of fuzzy magnitudes, corresponding to image details. With two values, background and foreground, the membership function is built based on the average gray level of each line, which is also used using the gray-level histogram as average weight factor.

By using an unthresholded range and a straightforward membership function, FRAT takes advantage of a simple fuzzy function to do the task for a noisy image. The average frequency is then used as a cost function for the selection of the optimal image threshold.

FRAT is part of a critical NASA system used to identify and track foreign object debris (FOD) during Space Shuttle launches. FRAT is also a key weapon tool used in the current investigation into the Space Shuttle Columbia tragedy.

FRAT benefits include:

- Exploitation of image pixel value histogram to avoid dealing with individual pixels
- Use of average magnitude as the criterion for selection of optimal threshold value
- Improvement in membership function to achieve more reliable and faster results

Commercial Opportunities

NASA is seeking companies to license this technology under its technology commercialization program, which seeks to stimulate commercial use of NASA-developed technologies. This technology is currently copyright protected, and a patent application is in process.

For More Information

If you would like more information about this technology or NASA's technology transfer program, please contact:

Robert Smith NASA Technology Applications Team 919.961.1491 919.961.1501 smith@nasa.gov	John Galtier NASA Technology Applications Team 919.961.1572 919.961.1509 john.galtier@nasa.gov
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Engineering Research and Technology, Inc.

FRAT: Our Potential Threshold

Then, just a little south, you'll likely of interaction entry in Ch.

Then, just a little south, you'll likely of interaction entry in Ch.

Then, just a little south, you'll likely of interaction entry in Ch.

Then, just a little south, you'll likely of interaction entry in Ch.

Catalog

Figure 9

Commercialization (Cont.)

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<http://nasa.rti.org/ksc/imaging>

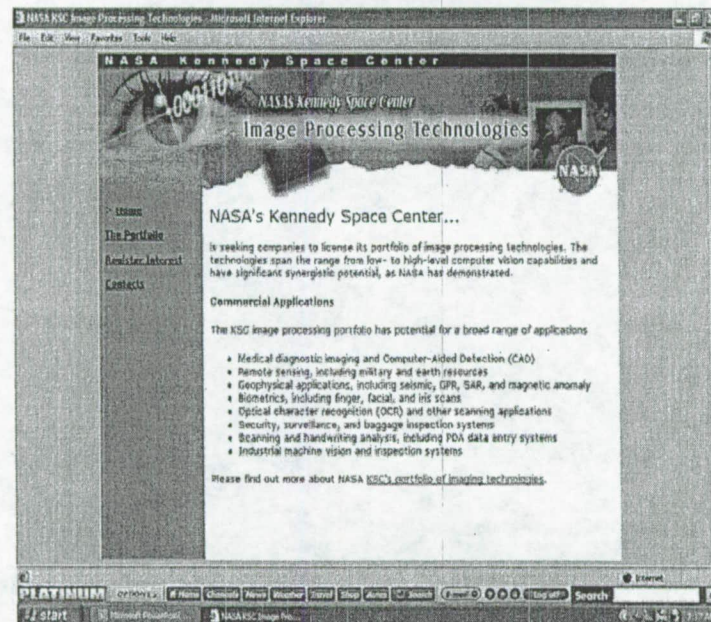



Figure 8




November 2002 www.techbriefs.com Vol. 29 No. 11

TECH BRIEFS
ENGINEERING SOLUTIONS FOR DESIGN & MANUFACTURING

Technology's Role In Homeland Security
Fuzzy Reasoning Aids Image
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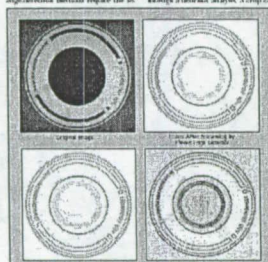


John P. Kinsinger, *Spain Under Pericles*

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Another school has been using a computerized system to calculate the optimal leucocyte gradient.

John A. Chase, Branch Office, Cleveland, Ohio.
 For Application, ADDRESS HERE.

herapeutic intervention that links the clinical and molecular studies in the context of cancer therapy. The course, which began in 1995, has been a major success story for the University of Illinois at Chicago. It has provided a critical mass of clinical investigators, through which the use of molecular biology in the study of cancer was fostered. The program has also been a source of inspiration to other cancer programs (see page 10) and has been instrumental in the recruitment of new faculty to the University of Illinois at Chicago.

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- **Processing:** easy to use software for visualization, and for processing, with integrated GPC and a powerful GUI (University of Virginia)

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Commercialization (Cont.)

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Spring Industrial Associates Meeting Agenda May 11-12, 2004

[Register online here](#)

May 11

- 8:00 Registration
- 8:30 CIS Overview
Mr. Joe Pow, Associate Director, CIS
- 9:00 Image Analysis via Fuzzy-Reasoning Approach: Prototype Applications at NASA
Dr. Jesus Dominguez, NASA Technology Applications Team
- 9:45 Student Research in Medical Imaging
Mr. David Fetzer (BS), Ultrasound Fingerprint Imaging: System Characterization and Material Identification
- 10:15 Break
- 10:30 3-D Laser Radar Using Arrays of Geiger-Mode Avalanche Photodiodes

http://www.cis.rit.edu/

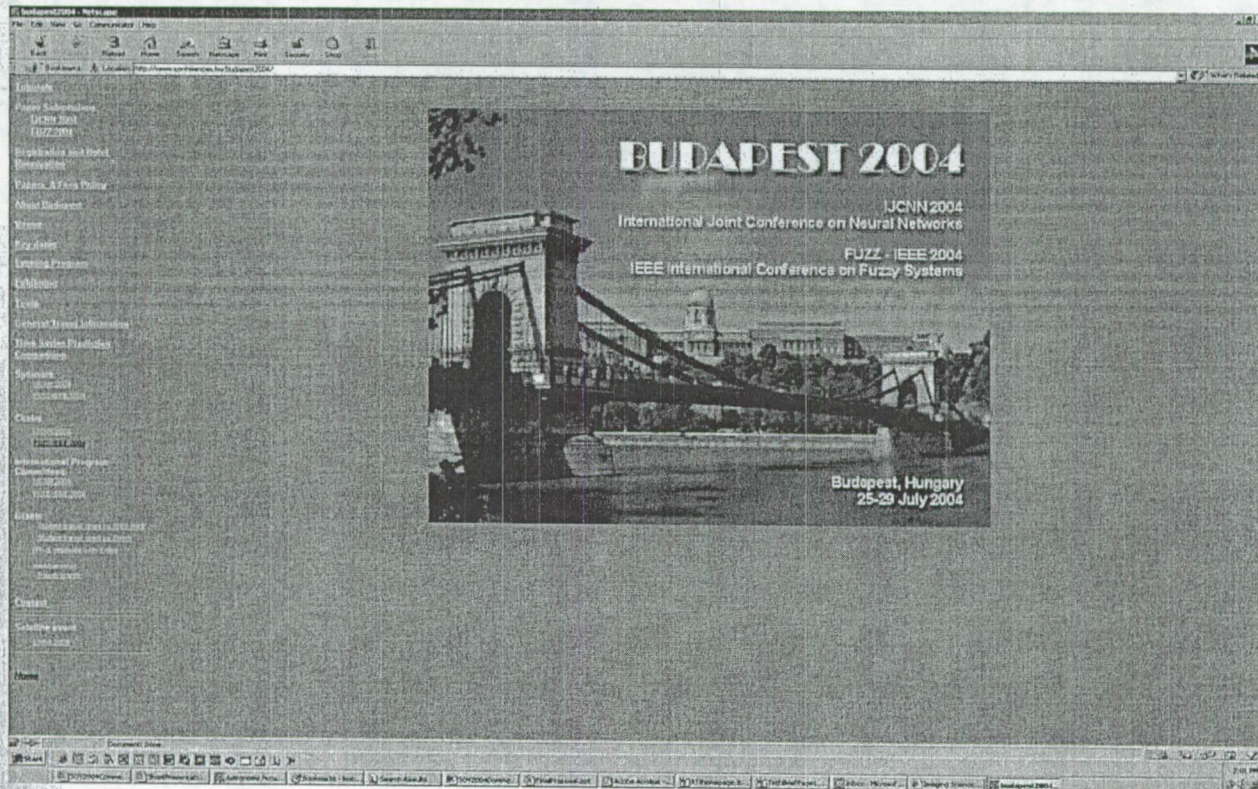
Start

Commercialization (Cont.)

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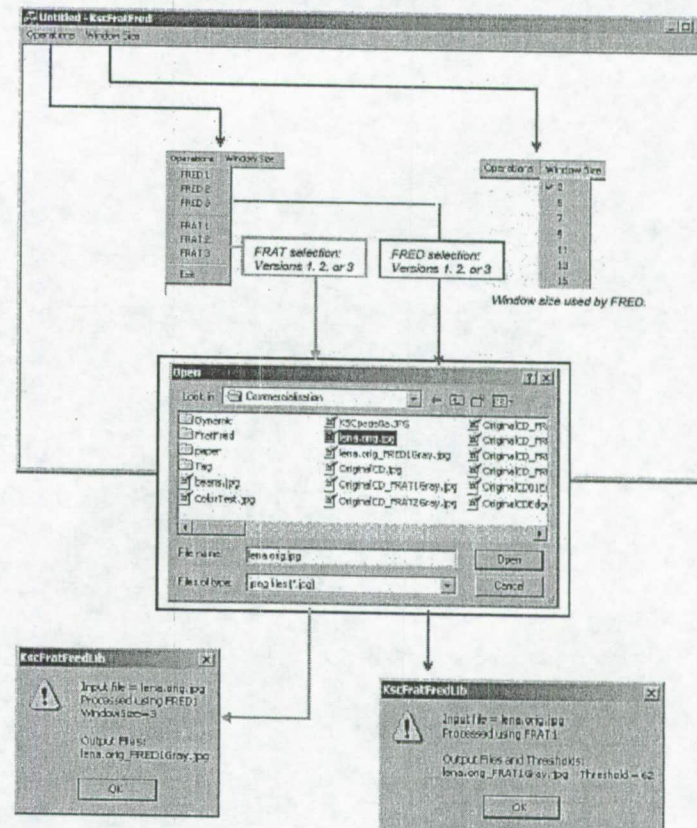
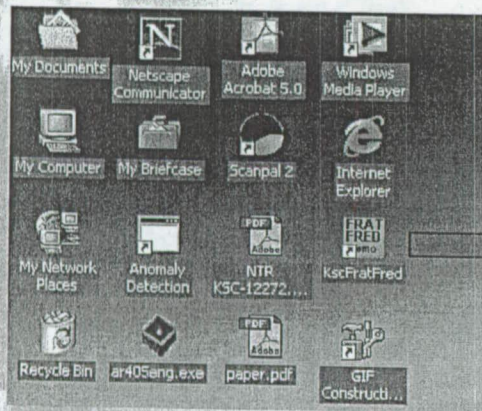


Commercialization (Cont.)

Kennedy Space Center



ASRC Aerospace Corp.



FRED output information:

- Input file.
- Version used.
- Window size.
- Output file.

FRAT output information:

- Input file.
- Version used.
- Threshold value.
- Output file.